# FARMING PRACTICE
# SOIL AMENDMENT WITH BIOCHAR

## IMPACT: NUTRIENT LEACHING AND RUN-OFF

### Reference 17

Borchard, N; Schirrmann, M; Cayuela, ML; Kammann, C; Wrage-Monnig, N; Estavillo, JM; Fuertes-Mendizabal, T; Sigua, G; Spokas, K; Ippolito, JA; Novak, J 2019 Biochar, soil and land-use interactions that reduce nitrate leaching and N2O emissions: A meta-analysis Sci. Total Environ. 2354–64. 10.1016/j.scitotenv.2018.10.060

### Background and objective

Biochar can reduce both nitrous oxide ($N_2O$) emissions and nitrate ($NO_3^-$) leaching, but refining biochar's use for estimating these types of losses remains elusive. For example, biochar properties such as ash content and labile organic compounds may induce transient effects that alter N-based losses. The aim of this meta-analysis was to assess interactions between biochar-induced effects on $NO_3^-$ retention, regarding the duration of experiments as well as soil and land use properties.

### Search strategy and selection criteria

A comprehensive survey of literature published between January 1, 2010 and May 31, 2016 was conducted, compiling 701 observations from 88 peer-reviewed publications accessed on the ISI Web of Knowledge. By using the term "biochar" in the "topic" field, 3328 publications appeared, but the number was reduced to 88 publications by abstract and full publication screenings. Studies were scrutinized using the following inclusion/exclusion quality criteria: They: 1) were conducted in soil (e.g., horticultural substrates were excluded); 2) included a minimum of three replicates per treatment; 3) followed a randomized design; 4) contained a "treatment" and a "control" such that the treatment was the same as the control in all aspects except for the inclusion of biochar; and 5) reported cumulative net $N_2O$ emissions, cumulative $NO_3^-$ leached and/or final $NO_3^-$ concentrations in soil.

### Data and analysis

The combined effect size over all available studies was estimated with a random effects model. The random effects model was chosen because we did not assume that the underlying true effect size is homogeneous over all included studies due to study conditions and environmental influences, and we further wanted to make generalizations beyond the observed studies (Hedges and Vevea, 1998). The random effects model was estimated with the DerSimonian-Laird estimator (DerSimonian and Laird, 2015). Each study was weighted by the inverse of its sampling error variance (inverse-variance-weighting), which ensures that studies with very small sample sizes do not have a severe influence on the estimates. The overall effect was estimated for cumulative $N_2O$ emissions, final $NO_3^-$ concentration, and cumulative $NO_3^-$ leaching. For assessing the heterogeneity of the meta-analysis, the $I^2$ index was used. The $I^2$ index indicates the percentage of the total variability among the effect sizes that can be explained by the between-studies heterogeneity.

| Number of papers | Population | Intervention | Comparator | Outcome | Quality score |
|---|---|---|---|---|---|
| 88 | Not specified | Soil amendment with biochar | No amendment | Metric: $NO_3^-$ leaching; Effect size: Logarithm of ratio of the considered metrics in the intervention to the considered metrics in the control | 0.9375 |

### Results

- Overall, $NO_3^-$ leaching was significantly reduced by 13% with biochar. Biochar significantly and consistently reduced $NO_3^-$ leaching by 26 to 32% in studies with an experimental time of >30 days.
- Biochars produced from lignocellulosic biomass and biochars produced at temperatures of >500 °C reduced $NO_3^-$ leaching.

### Factors influencing effect sizes

- Soil texture : Only coarse textured soils (i.e. sand) showed a reduced leaching of $NO_3^-$.
- Soil type : Soil $NO_3^-$ leaching was exclusively reduced in Cambisols (i.e. soils of limited age), and semi-arid soils (e.g. Calcisol, Solonetz)
- Biochar application rate : Low biochar application rates of <10 Mg $ha^{-1}$ increased $NO_3^-$ concentration in soils. Larger biochar application rates (e.g., >10–20 Mg $ha^{-1}$) tended to reduce $NO_3^-$ leaching.
- Fertilisation management : $NO_3^-$ leaching remained unaffected for soils managed by application of biochar in combination with organic fertilizers. Leaching of $NO_3^-$ was reduced by biochar in unfertilized soil and when the fertilizer application rate was below 150 kg N $ha^{-1}$. Leaching of $NO_3^-$ progressively increased in response to increased N application rates (i.e. -26% for <150 kg N $ha^{-1}$, −7% for 150–300 kg N $ha^{-1}$, 46% for >300 kg N $ha^{-1}$). Hence, over all N fertilizer application rates, the $NO_3^-$ leaching reduction was not significant (i.e. +3% with mineral fertilizer, −7% with organic fertilizer, and −35% with organo-mineral fertilizer).
- Crop type : For biochar applications to grassland $NO_3^-$ leaching were not affected.

### Conclusion

$NO_3^-$ leaching was significantly reduced by 13% with biochar. Results support the notion of a dose-response relationship of biochar application on $NO_3^-$ leaching, which hints towards the interesting possibility of using biochar as a carrier matrix for "carbon-fertilizers".